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ABSTRACT

This paper introduces and reports upon lessons learned during the development phase of the Lord Kelvin Middle School Science Program. For the past two years, a set of tools to help middle school students learn science in a way that uses the full power of today's technology has been under development. Lord Kelvin is a robust collection of science activities, organized in modules, that incorporates probeware, sophisticated simulations, multimedia support for instruction, multiple assessment components, and comprehensive reporting tools. The activities bridge the gap between traditional and high tech science. The project, funded by the National Institute of Health, joins the talents of a high tech engineering firm with experienced instructional designers to produce a unique learning experience for middle school students. (Author)

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The Lord Kelvin Project: Middle School Science for the 21st Century

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Abstract This paper introduces and reports upon lessons learned during the development phase of the Lord Kelvin Middle School Science Program. For the past two years, we have been developing a set of tools to help middle school students learn science in a way that uses the full power of today's technology. Lord Kelvin is a robust collection of science activities, organized in modules, that incorporates probeware, sophisticated simulations, multimedia support for instruction, multiple assessment components, and comprehensive reporting tools. The activities bridge the gap between traditional and high tech science. The project, funded by the National Institute of Health joins the talents of a high tech engineering firm with experienced instructional designers to produce a unique learning experience for middle school students.

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Introduction

Everyone envisions a future in which workers will use electronic tools to help them carry out the tasks for which they have been employed. It is often difficult to predict what these electronic tools will look like, yet educators feel obliged to establish curricula designed to develop students' technological skills. We believe that this is the wrong approach. Rather than focusing on technological skills, the Lord Kelvin Experience *assumes* the technology, while helping students learn how to learn. This is easy to say, but how is it accomplished? All learning involves gathering information, organizing the information, and operationalizing the information, that is, bringing the newly acquired knowledge to bear on a task. Living in the information age means that information will be (and is) coming to us rapidly from multiple sources - TV, radio, text books, expert commentary, our friends, in multiple ways - video, audio, text, word-of-mouth, first hand experience. Collecting, organizing, selecting and reporting information and the knowledge distilled from it is a formidable task. The Lord Kelvin interface is designed to optimize student performance in these areas. The interface provides a consistent, predictable system to manage multiple sources and channels of information and experience for students as well as teachers. The interface also allows the level of learning to be customized so that students can "ramp up" to more challenging modes of inquiry. Although it is very sophisticated, in a very short time the interface becomes transparent, allowing the student to focus on content and process issues.

The development of the Lord Kelvin Science Program, which has been funded by the National Institute of Health, has been guided by some basic pedagogical beliefs and principles:

> Through a tight interaction between a knowable curricular structure and a consistent user-interface, a learning environment can support inquiry from multiple perspectives using multiple learning models.
>
> Though students may require different levels of guidance, they can understand and relate to the complexity inherent in the study of modern science.

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Assessment of student accomplishment should be multifaceted and relate to context sensitive information as well as global scientific principles and educational standards.

Teachers can and should take an active role in modifying and/or developing the educational tools their students use to learn. Since teachers are under severe time constraints, powerful editing tools should be at their disposal.

Development began by isolating specific science topics addressed by the National Science Standards but not adequately addressed by current science programs. We then began work collecting, selecting, and developing educational components, or *modules*, centered on the following aspects of each topic:

Background Information
Learning methodologies in three dimensions: a step-by-step model, a guided model, and a task specific free-inquiry model
Hands-on experimentation
Simulated experimentation
Multiple types and levels of assessment
Video and audio clips related to instructional aspects of the component
Multimedia clips related to content

Simultaneously, we began designing and developing an interface (see Appendix) that would provide consistent access to each of the above elements, in a way that would follow and expand upon current usability principles for educational software.

Structure of the modules

The Hook. Each module contains a "hook" or question to motivate and stimulate the student to carry out the investigation. For example, we introduce the debate about cell phone radiation by investigating exactly when cell phones produce radiation.

The Challenge. The challenge is a more specific goal statement. The challenge sets up the investigation and provides motivational cues to help the student get started.

Background information. Each module contains a variety of information related to the concept, and larger scientific principles related to the core concept. The information is organized in a context sensitive way, and relates directly to the investigation at hand, but also offers the student a chance to explore the concept in depth. A typical background session might involve reading about generic science strategies, investigating core content, browsing selected readings and examining other resources related to the core concept.
Methodology. The investigation is conducted using one of three models depending on which learning strategy has been chosen by the instructor. In the step-by-step approach, a "cookbook" methodology is presented for the experimentation. In the guided approach, a less specific

procedure is specified. Finally, in the inquiry approach, statements related to the goal state are given which motivate students to conduct the investigation

Experimentation. To carry out this investigation, students rely on a system of probeware we have developed which measures radiation in the 2.4 Gigahertz range. Each module has probeware associated with it, which has been specifically designed for this program. The probeware is programmable, and over the course, students should begin understanding how to interact with programmable electronic tools. Data collected by the probe may be displayed in a variety of formats, selectable by the student. Students may also use a simulation that simulates the use of the probe. When using the simulation, the data output is collected in precisely the same way as the as the output from the probe.

Assessment. The assessment element includes multiple approaches to assessment and addresses misconceptions, content and process knowledge, and application. Wherever possible, student assessment is encouraged, and student's assessment abilities are developed throughout the program using a variety of strategies.

Other Features. The Lord Kelvin environment contains an elaborate glossary. Any word found in the glossary appears to be "hot" in any system window. Clicking on the word delivers the glossary, and in addition, a series of games designed to reinforce memorization of vocabulary are available. Modules often contain videos that illustrate how to conduct an experiment, or show some application of the concept. Of course, diagrams, charts and other activities are used to explain, analyze, and compare data in a variety of contexts.

Brief overview of the interface

One of our self-imposed prime directives in interface development was to reduce or minimize the cognitive load placed on the student when accessing our materials. In other words, we were anxious to develop an environment in which windows didn't "pileup" requiring the student to move, close, manipulate and otherwise tend to the clutter on the desktop. We decided to create a series of fixed windows that would slide into place when information was requested. We have integrated the windows with the content by using specific windows for the same type of information across modules. When students request to see a module's *Challenge* component, it always appears in the same window. Each window has a set of context sensitive tools relating to activity in that window. Thus, a student can copy, print or save information in the window as well as apply tools such as rulers or stopwatches to the activity in the window. The student requests to view a window through the use of a "Personal Study Instrument" or what we call a PSI tool. The PSI tool always appears in lower right of the screen, and is a control center that allows a student to direct the flow of information to the screen and within the learning environment.

The PSI Tool not only helps the student navigate from one learning experience to another, it provides a motivated teacher with a concise, straightforward approach to designing lesson modules. To a teacher, the PSI tool represents an organizer, an interactive table of contents for each lesson module. Each lesson component will be "launched" from the PSI tool. If a teacher feels that a component of a module is inappropriate for his or her students, using the PSI tool editor, they may "inactivate" that access button from the PSI menu, thereby removing the button from the PSI tool. If the teacher prepares additional information about a lesson module, the

teacher may "link" that information to the lesson by creating a new button in the PSI tool. In this way, teachers can customize Lord Kelvin modules. In fact, using the PSI tool editor, teachers can assemble entirely new lesson modules from materials they have previously prepared.

Any teacher who desires to create new Lord Kelvin modules can do so by creating a PSI tool to address the various aspects of the module being designed. Doing so, the teacher combines lesson planning with lesson material documentation. Creating buttons and button sets for the PSI tool gives the teacher a new metaphor for thinking about lesson support. In addition, the PSI tool provides a method to differentiate content that supports different learner groups. Even if the teacher chooses not to author modules, modules may be customized. All packaged Lord Kelvin modules, for example, support learners at three levels: (1) Cookbook - a step by step approach to science investigations (2) Guided - a mode which includes a clear statement of the problem along with ideas about how to solve it, and (3) Inquiry - a mode involving a more ill-structured problem statement, and challenges that may have no cut and dry solution. The teacher can easily choose which level is appropriate for his or her class, group or individual student.

We decided to develop program graphics, media, and simulations using a photorealistic model. Although some early research (Dwyer (1978), Travers & Alvarado (1970)) showed that realistic representations contained too many irrelevant details that interfered with learning, others (Berry, L.H. (1991), Hannafin (1987)) believe complexity to be a crucial factor in the visual learning process, and that photorealism supports it. Although Heim (1998) suggests that computer users are polarized about photorealism vs. pure fantasy in virtualization, initial reactions to our photorealistic simulations were more positive than reactions to two-dimensional models. The project will generate a doctoral study related to this decision, as well as to others in our design.

Interaction between module components

In Lord Kelvin, a learner examines a concept or elements of a concept from many perspectives. While it is sometimes true that in the Lord Kelvin environment the same content will be addressed using different information channels (text-based readings and video, for example), it is equally likely that the same content will be addressed in a different context or learning mode. For example, since middle school students often have trouble choosing appropriate graphing strategies, Lord Kelvin modules incorporate activities that address graphing both implicitly and explicitly. In addition to a text-based reference about graphing, students will have to make decisions about graphing types when doing real experiments and when doing simulated experiments. The decisions about graphing interact with the students understanding of how data is received from a probe, and in many cases how they have calibrated the probe. The interplay between math and science concepts and between the various elements of the module strengthens understanding. Simulations combined with real-experimentation offer students the opportunity to explore a wider range of variables more rapidly.

In some cases, the simulations used in our program are virtual representation of hands-on experiments, in other cases; the simulations are unrelated to the hands-on experiences of the student. Pedagogical decisions about the content (interacting with technical capabilities, of course) have guided our choices in this regard.

Other constraints placed on this interface development, besides our prime directive to keep it simple, involved scalability issues and a desire to be able to deliver the environment in a web context. These issues required much attention, but as the development process continued,

the congestion issue reemerged several times and we had to remain vigilant about maintaining simplicity in the interface. It was difficult not to add new windows, or new components that would clutter the student's learning environment. Our commitment to simplicity in the interface has carried over to teacher-centered environments involving module editing, document construction and network activity.

Though out the design and development process, we have witnessed, and promoted a strong interaction between interface elements and learning goals and objectives. In the development of learning software, issues of usability must be coupled with strong pedagogical convictions. In our case, we have promoted inquiry along multiple inquiry paths, from multiple perspectives, in ways that incorporate many approaches to learning. Students are given both mastery and performance oriented goals, similar to those outlined in Pintrich, P. R. (2000). The strength of the learning experience is based on the consistent application of systemic self-imposed usability rules coupled with robust lesson development. Students will be offered a consistent, comfortable learning environment in which to explore complex scientific relationships. It is our hope that the students' performance will be augmented by the software based inquiry tools and consistent environment we have constructed for them.

Summary

The Lord Kelvin Experience encourages scientific inquiry by involving the learner in several activities that address a single concept from multiple perspectives. For example, a typical module might include a virtual investigation employing a simulator, a hands-on investigation using a state-of-the-art probe with a video segment explaining how to set up the experiment, a reading with comprehensive background information, a glossary with context sensitive help in the form of educational games, a motivational "hook" delivered by a computer agent to get the student started, and eight or nine assessment tools designed to help the student and the instructor assess prior knowledge, conceptual understanding, process and technological skills, and potential applications of the core concept. In order to carry out a robust examination of the concept at hand, the student must be able to navigate within the module from one activity or information source to another, sometimes compiling information, making graphs, and collecting data along the way. The PSI Tool, or Personal Study Instrument allows the student to navigate freely within a Lord Kelvin module. At any point, the student can employ the Notepad to save pertinent information about the concept being studied. Ultimately, the student may transfer and edit the information gathered to make a persuasive final report. Sophisticated reporting tools make this task easier.

The student working in the Lord Kelvin environment is able to employ, apply, and interact with powerful learning tools that help augment the study process at all levels. Teachers working with Lord Kelvin can freely modify any learning activity and is encouraged to create new activities within the environment through the use of built in editors.

Our goal was to develop a robust teaching and learning environment that would replace dozens of software tools in a way that would allow a short learning curve. Further, we wanted to bring the study of science into alignment with the science principles that students interact with everyday. Although we have included some traditional experiments in the project, many of the inquiries involve modern electronic and scientific curiosities, such as cell phone radiation and laser applications. As students become familiar with interactive, programmable probeware, they will begin to understand how to align their tools with their investigative requirements and goals to

augment their performance. By working with simulations, they will interact with the variables affecting their results. It is our hope that students investigating modern phenomena using modern tools will recapture the wonder and curiosity upon which every true scientific investigation builds.

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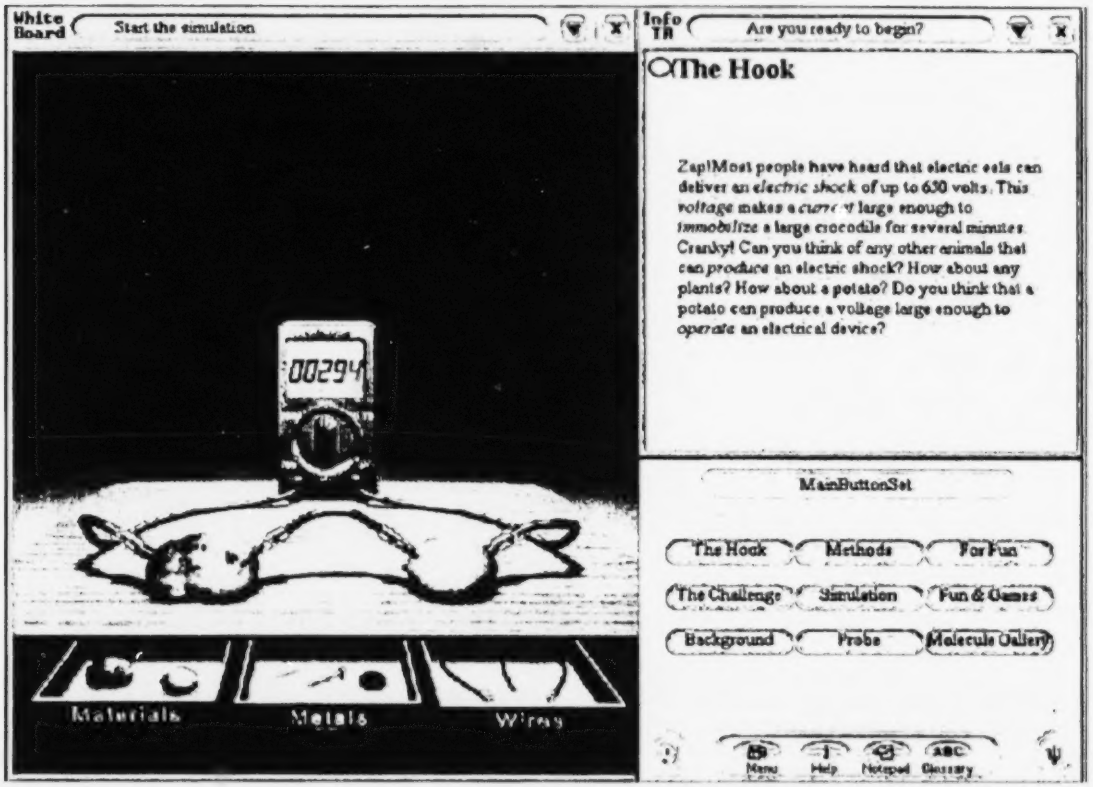
Appendix


White Board
Start the simulation
Info TR
Are you ready to begin?
The Hook
Zap!Most people have heard that electric eels can deliver an electric shock of up to 630 volts. This voltage makes a current large enough to immobilize a large crocodile for several minutes. Cranky! Can you think of any other animals that can produce an electric shock? How about any plants? How about a potato? Do you think that a potato can produce a voltage large enough to operate an electrical device?
00294
Materials
Metals
Wires
MainButtonSet
The Hook
Methods
For Fun
The Challenge
Simulation
Fun & Games
Background
Probe
Molecule Gallery
Menu
Help
Notepad
Glossary

Sample screen from the Lord Kelvin Project: *Simulation, Hook and PSI Tool*

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